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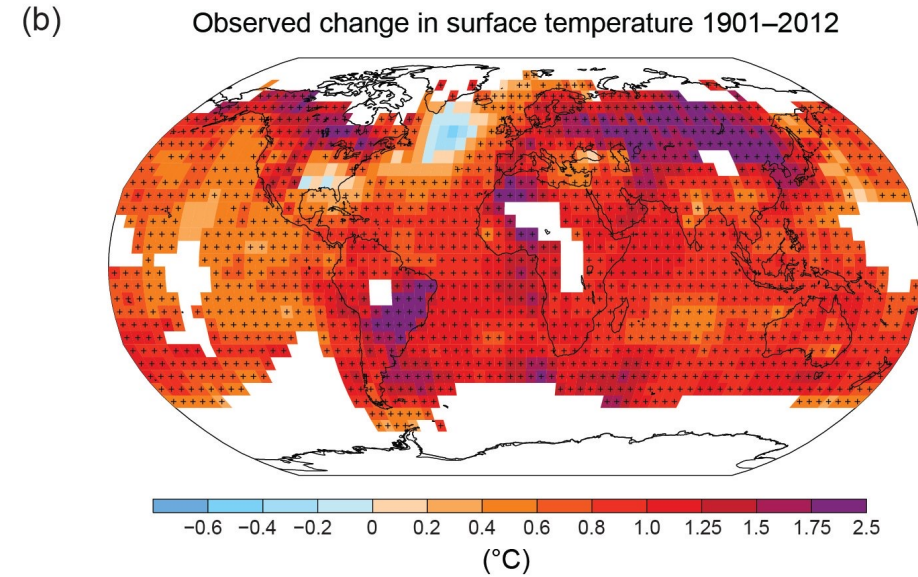
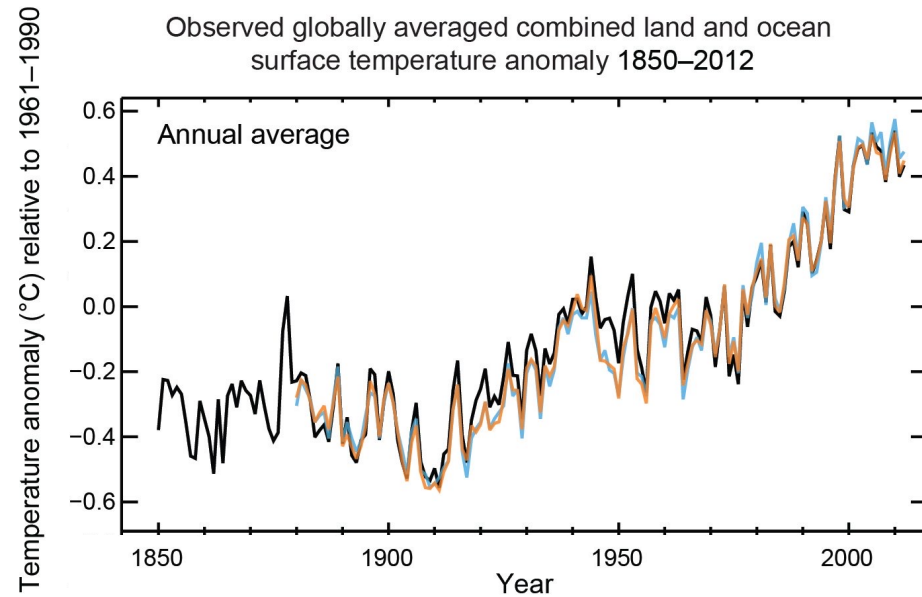


# Changing climate and melting ice: perspectives from field work and climate modeling

Carolyn Branecky Begeman, Los Alamos National Laboratory

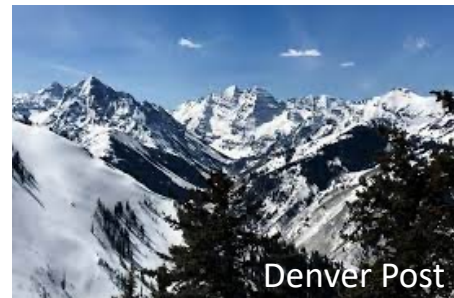


# The last century has seen marked increases in global temperature



with a wide range of impacts

IPCC AR5





# Earth System Modeling: a way to understand and “predict” climate impacts

Atmosphere

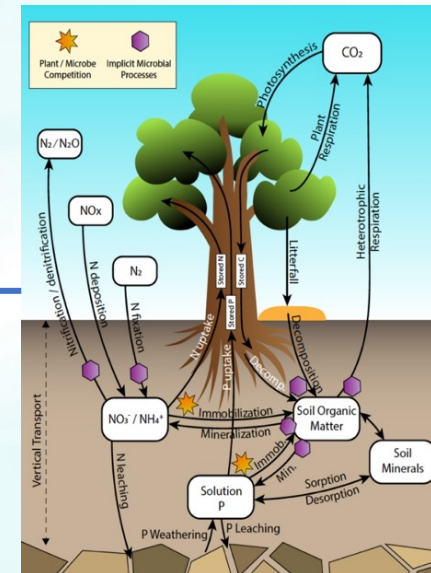
Ocean

**E<sup>3</sup>SM** Energy Exascale  
Earth System Model

Ice sheet

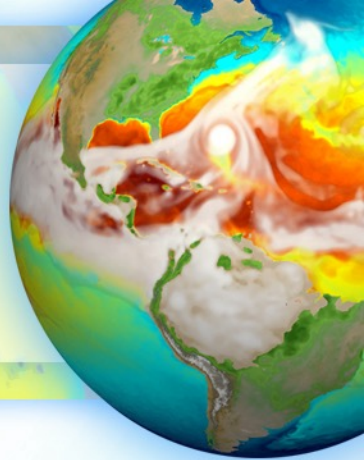
Sea ice

Land





# Earth System Modeling: DOE's science focus areas



## Water Cycle

How does the interaction of humans and the physical environment determine water availability and water cycle extremes?



NM In Depth

## Biogeochemistry

What is the impact of biogeochemistry changes on energy-sector decisions?  
For example, land cover changes and ocean acidification



NOAA

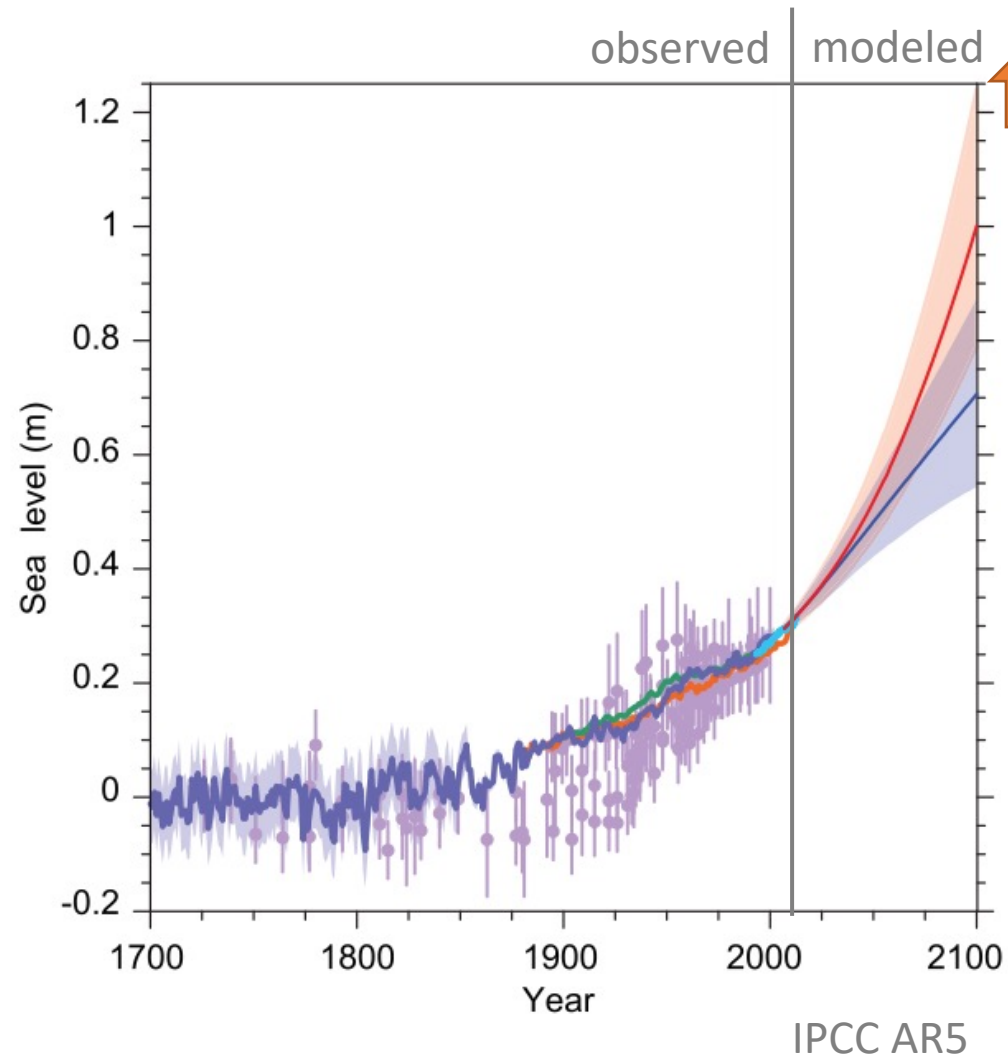
## Cryosphere Systems

How will the cryosphere respond to climate changes and contribute to sea level rise and increased coastal vulnerability?



National Geographic

# How much sea level rise can we expect?



Emissions continue to increase

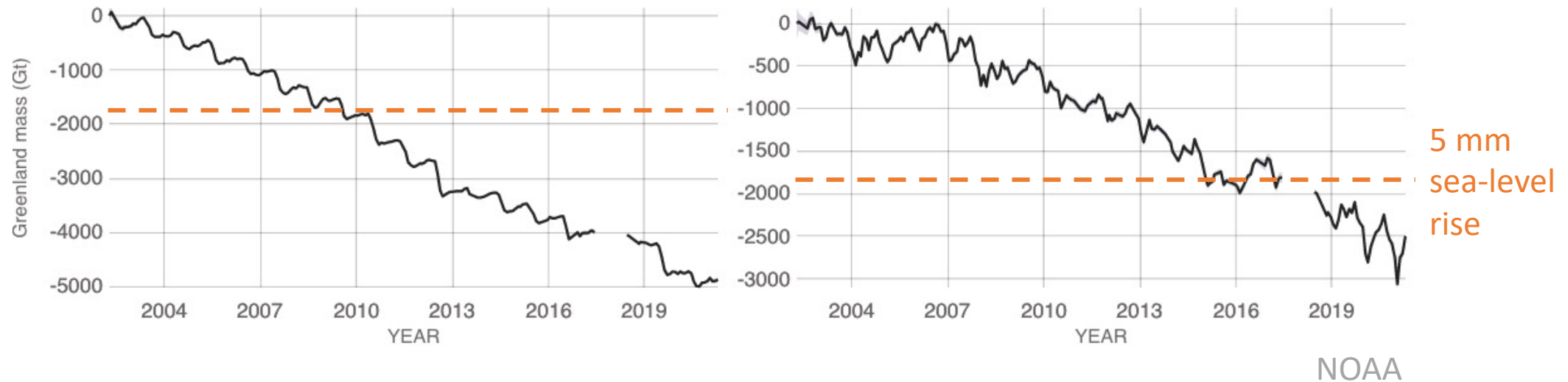
Emissions start declining in 2020

Ice sheets could be major contributors to sea level rise

6 m in Greenland

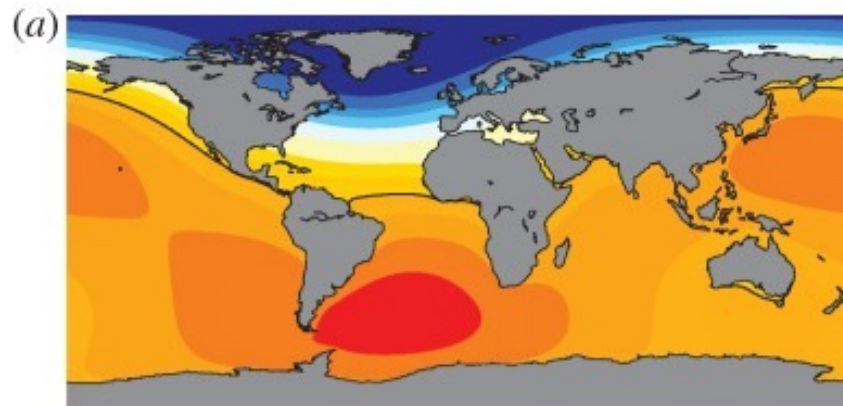
58 m in Antarctica

## Both Greenland and Antarctica are losing ice

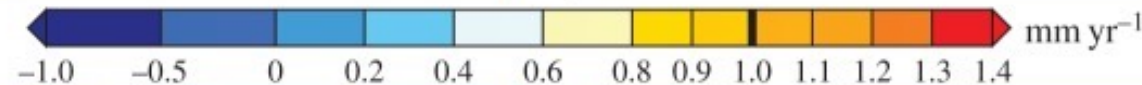
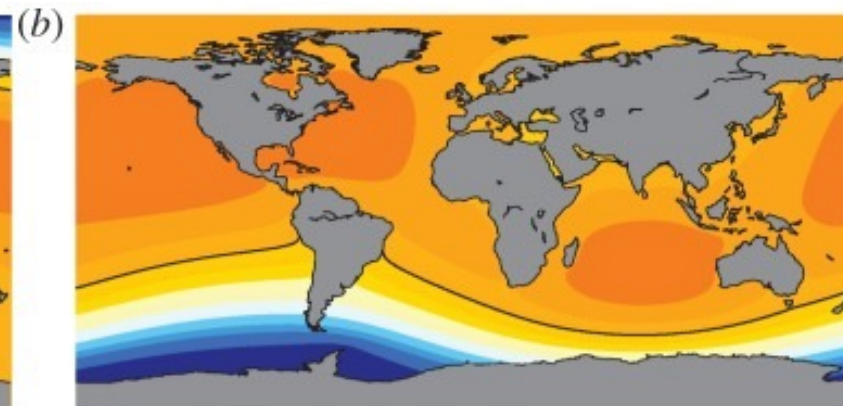


It matters which ice sheet the water comes from  
1 mm of global sea-level rise from

Greenland



West Antarctica

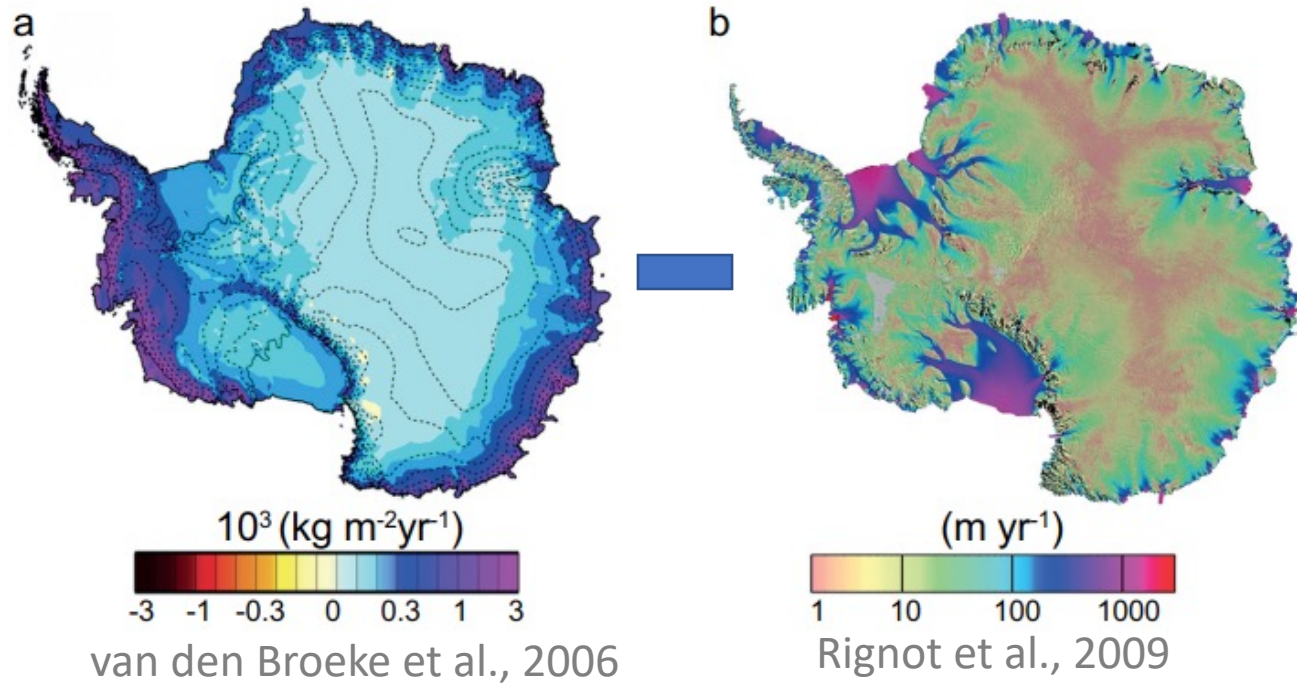




# Ice sheets 101

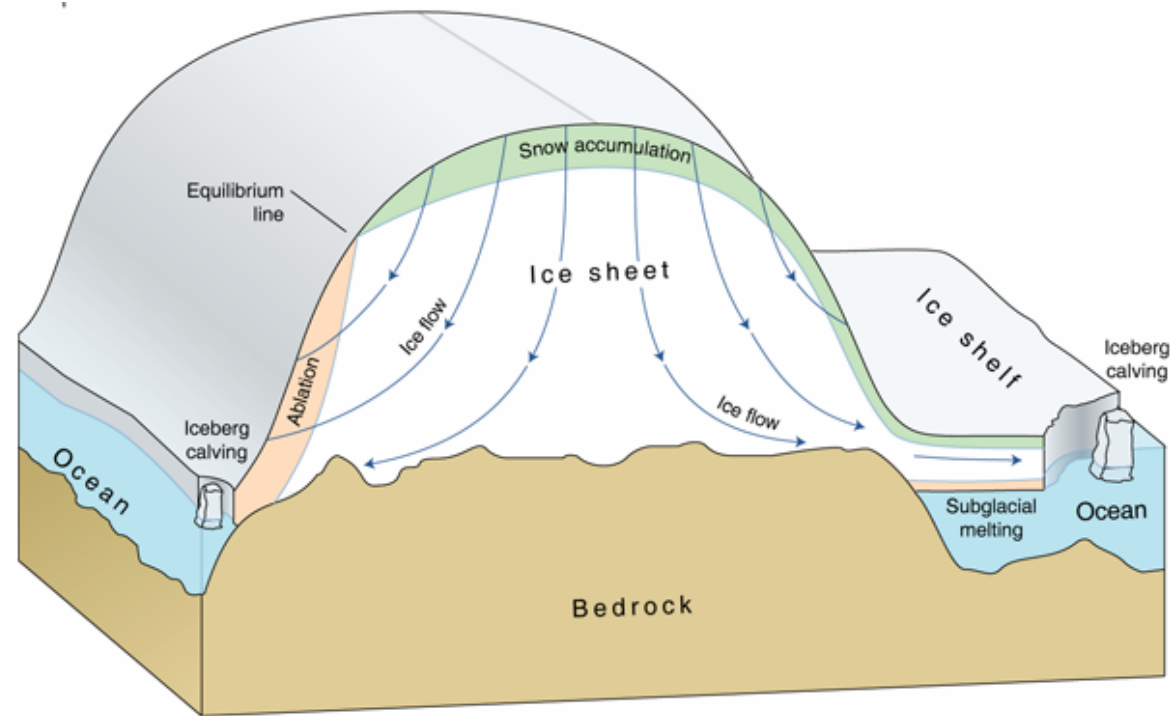
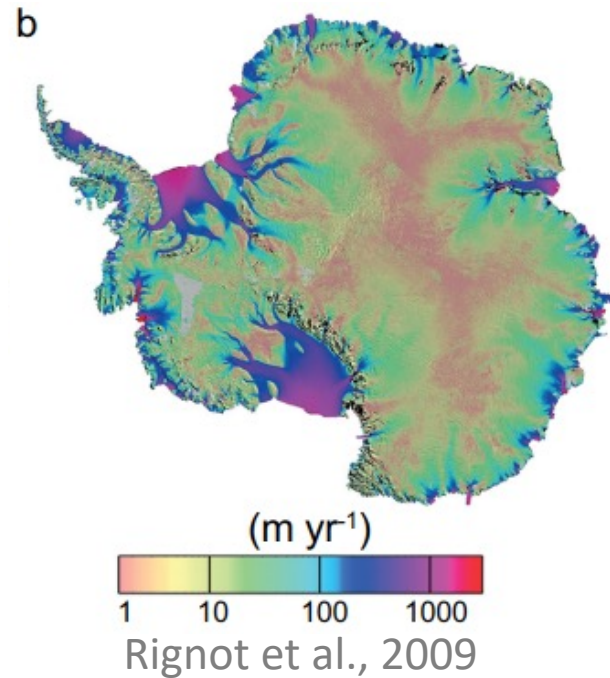
Snowfall

Ice flow into the ocean



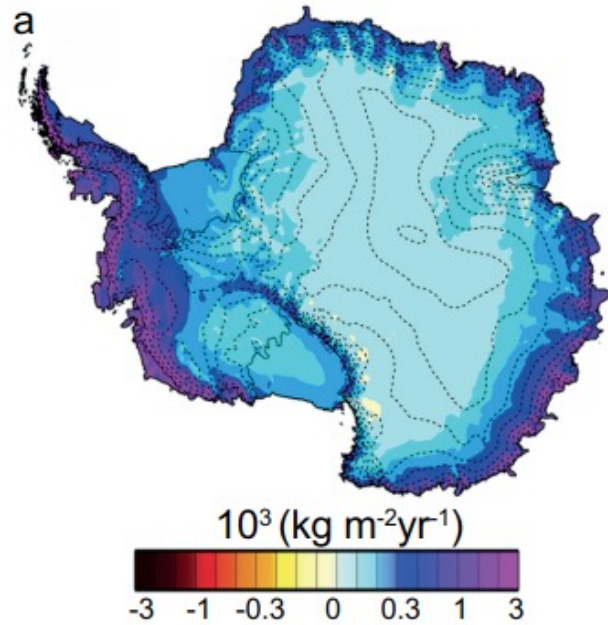
# Ice sheets 101

## Ice flow into the ocean



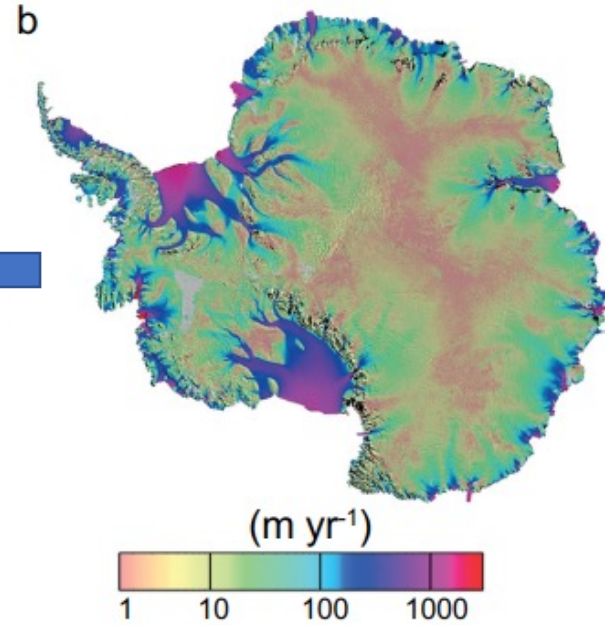
# Ice sheets 101

Snowfall



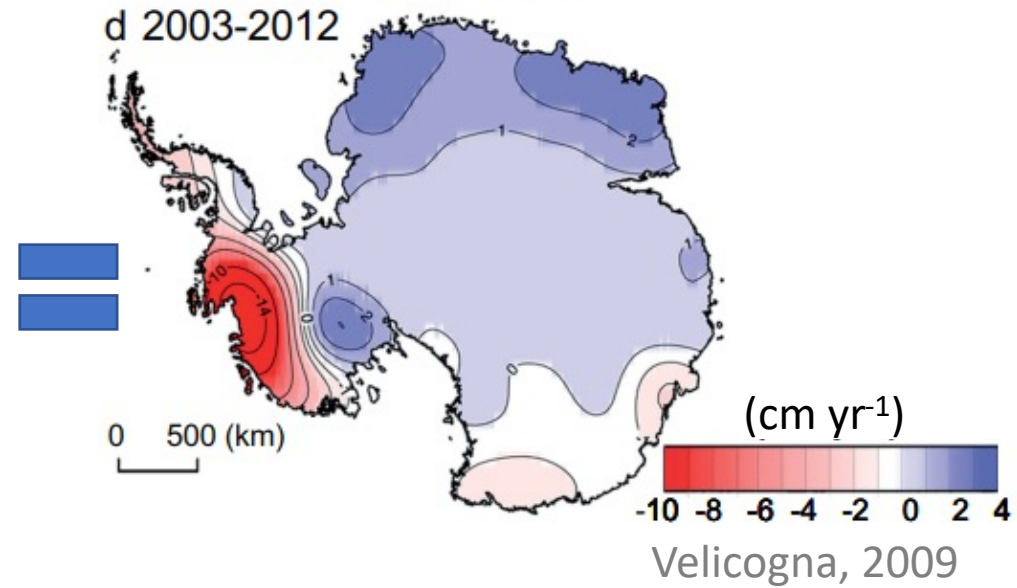
van den Broeke et al., 2006

Ice flow into the ocean



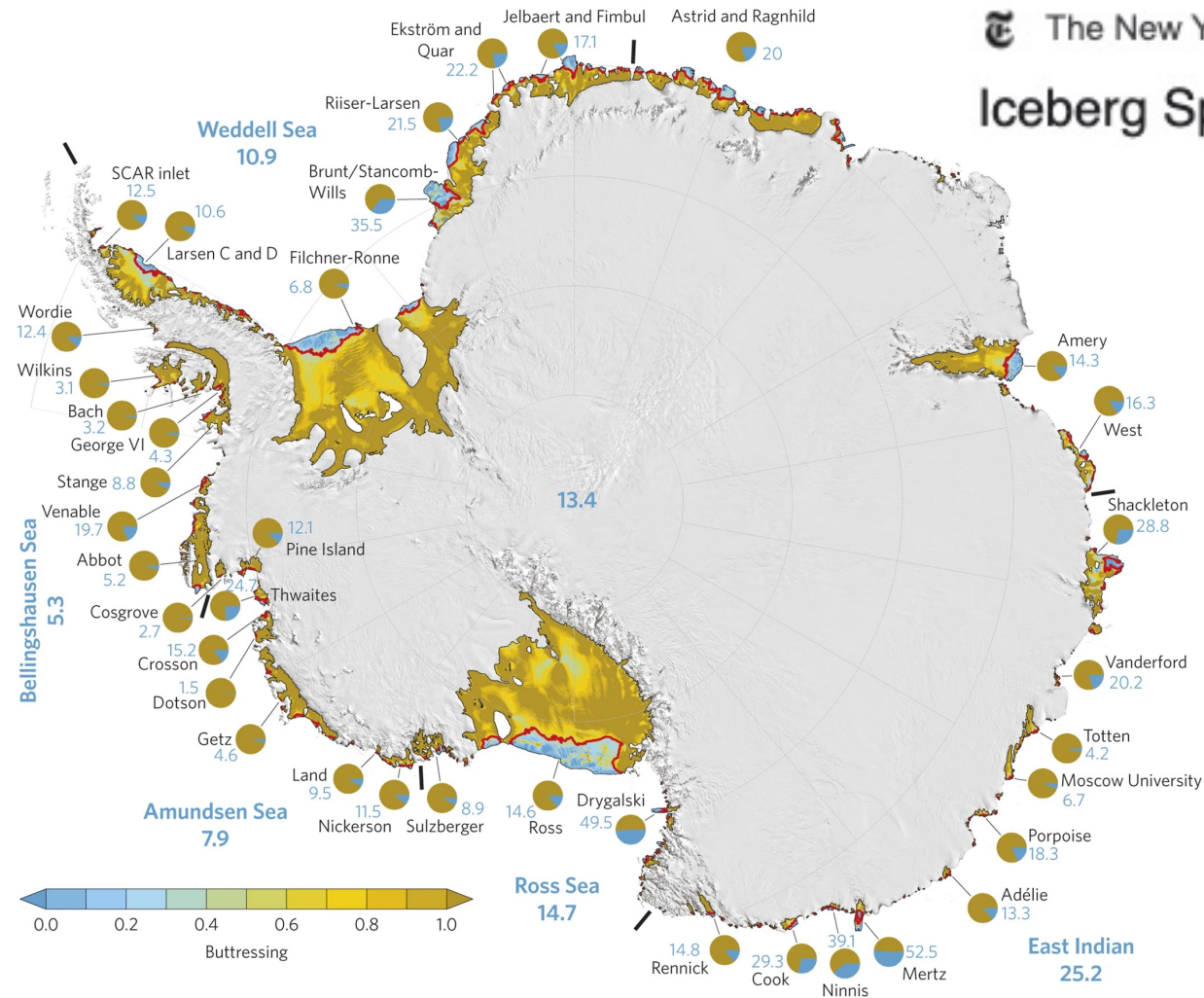
Rignot et al., 2009

Loss of glacial ice, Sea level rise



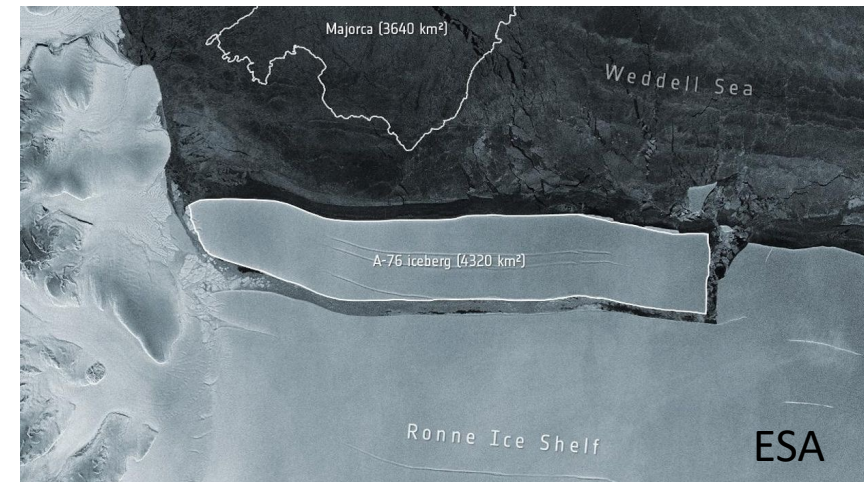


When enough icebergs calve, the ice sheet flows faster



The New York Times

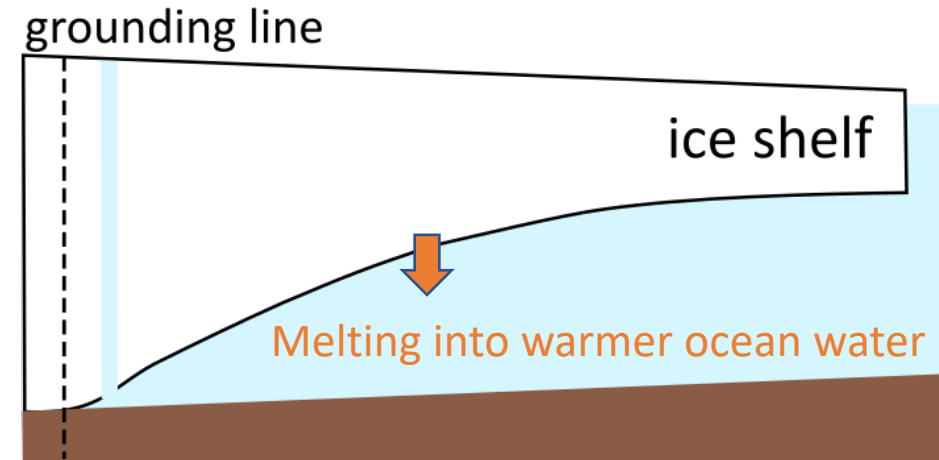
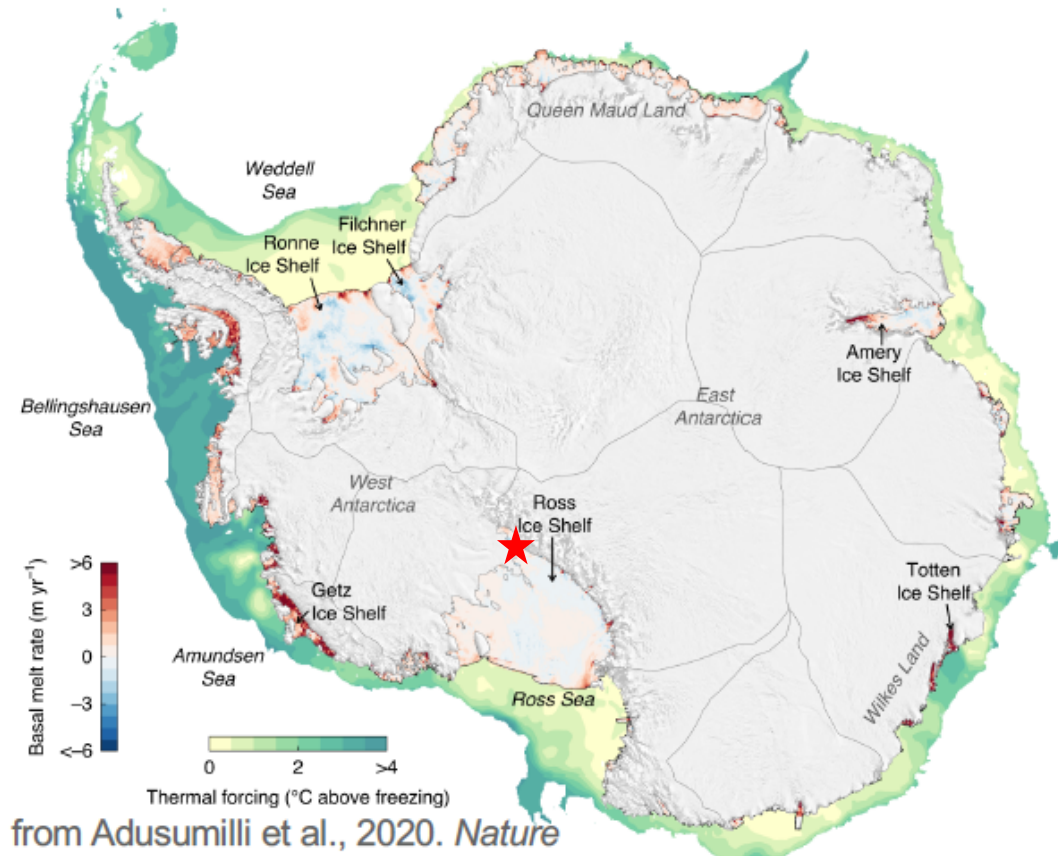
## Iceberg Splits From Antarctica, Becoming World's Largest



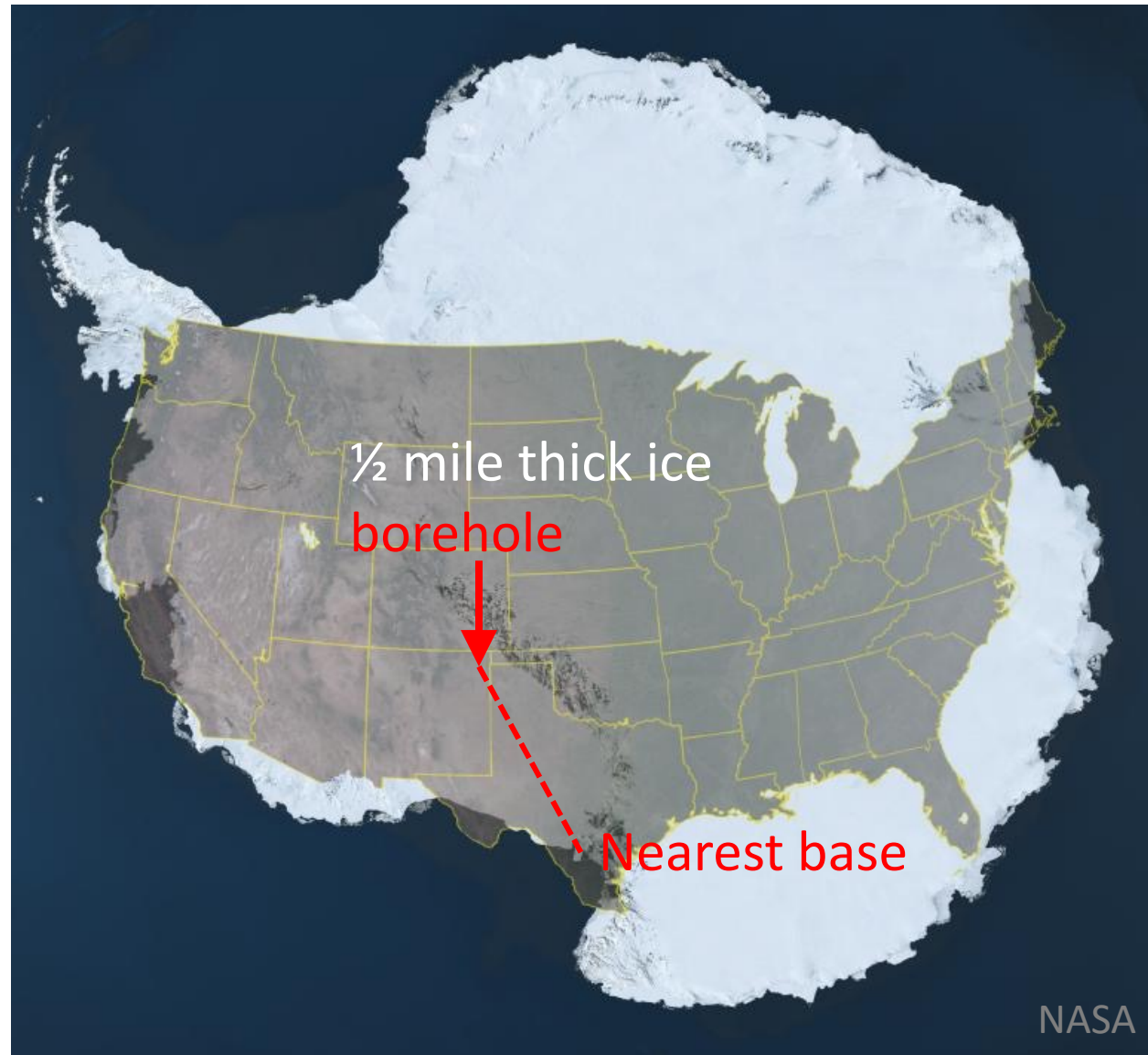


# When ice shelves thin, the ice sheet flows faster

Thinning mostly happens by melting from below



# The WISSARD project: drill below Ross Ice Shelf





Hot water drilling

borehole



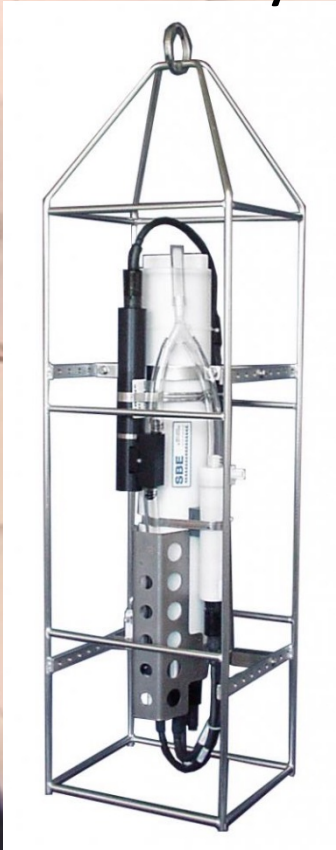
Drilling platform





# Ocean observations

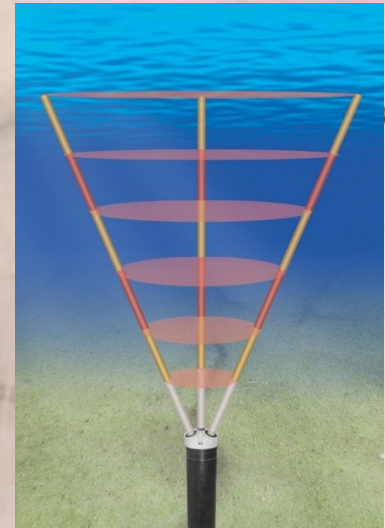
Temperature  
Salinity



CTD

Jill Mikucki

Current velocity



ADCP

Tim Hodson



Slow melting due to cold ocean water and slow currents

Gravel-sized bed



# Earth System Modeling: a way to understand and “predict” climate impacts

Atmosphere

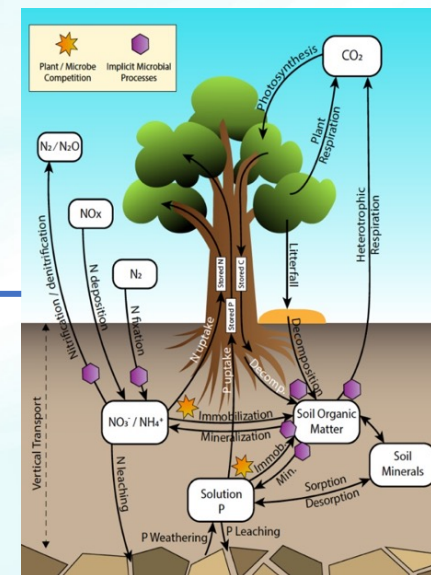
Ocean

**E<sup>3</sup>SM** Energy Exascale  
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Ice sheet

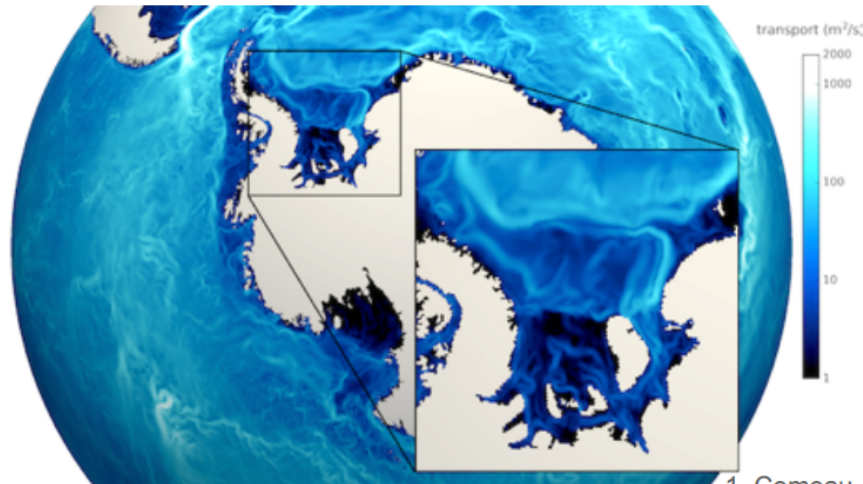
Sea ice

Land

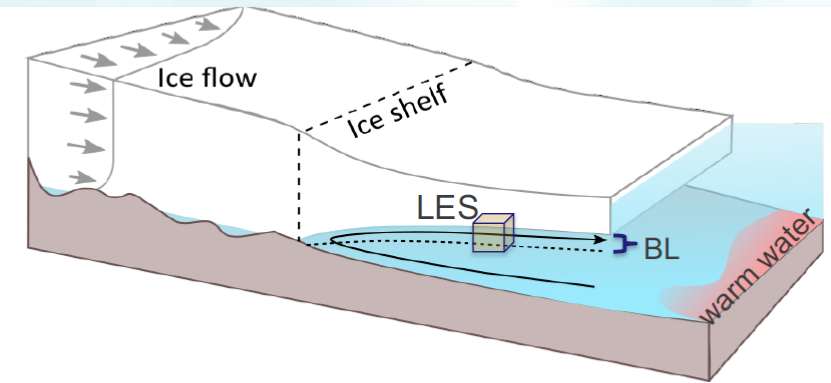


# My latest work: modeling interactions between ice sheets and the Earth system

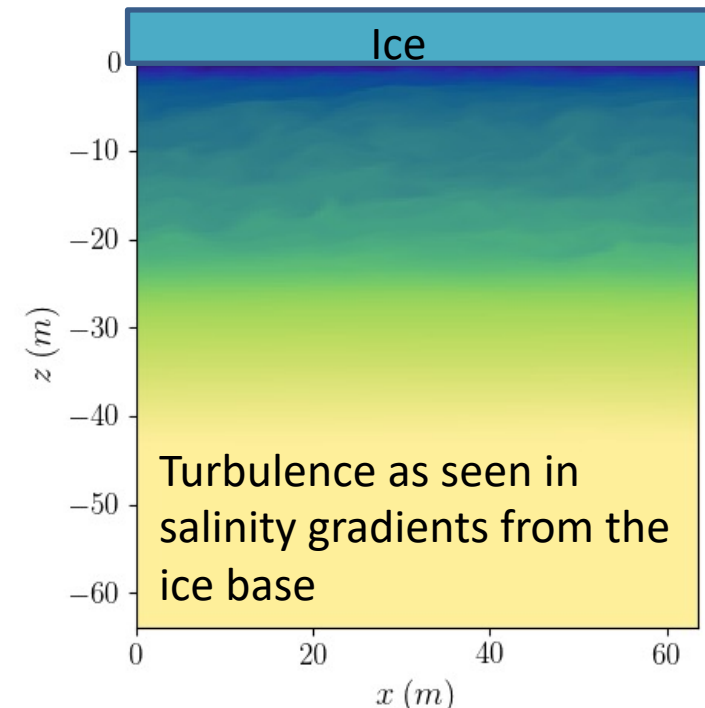
- E3SM recently added the capability of simulating ocean circulation in ice-shelf cavities and computing ice-shelf melt rates<sup>1</sup>



1. Comeau, Begeman et al., 2020 (in pre)



- High resolution ocean modeling in ice shelf settings to learn more about how sensitive ice melting is to temperature
- Sophisticated gridding techniques to enable the ice-shelf ocean cavity to evolve as icebergs calve and the coastline retreats





# Thank you

